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(54) Abstract Title
Four-terminal impedance measuring device with a contact detection arrangement

(57) A four-terminal impedance measuring device comprises current supply lines H_c, L_c and voltage detection lines H_p, L_p connected to first T_H and second T_L terminals of a component under test R_{dut}. A resistor R_{H1}, R_{L1} is connected between the said lines associated with the first terminal T_H and those of the second terminal T_L of the said component respectively. Resistors R_{H2}, R_{L2} are connected between the current supply line associated with one terminal of the said component and the voltage detection line associated with the other of the terminals of the said component and vice versa. An alternative arrangement discloses a four-terminal impedance measuring device in which a resistor is connected between a current supply line associated with one terminal of the said component and the voltage detection line associated with the other of the terminals of the said component and vice versa. A voltage following amplifier may be arranged to improve the impedance of the voltage detector to ac signals. The device may indicate if and/or which contact is faulty and may provide some compensation adjustment for the fault.

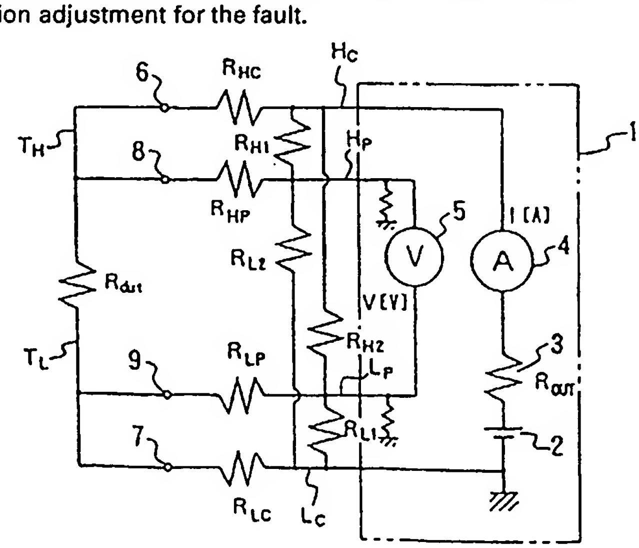

FIG. 5

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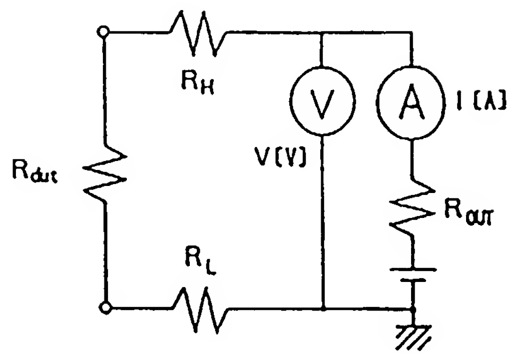
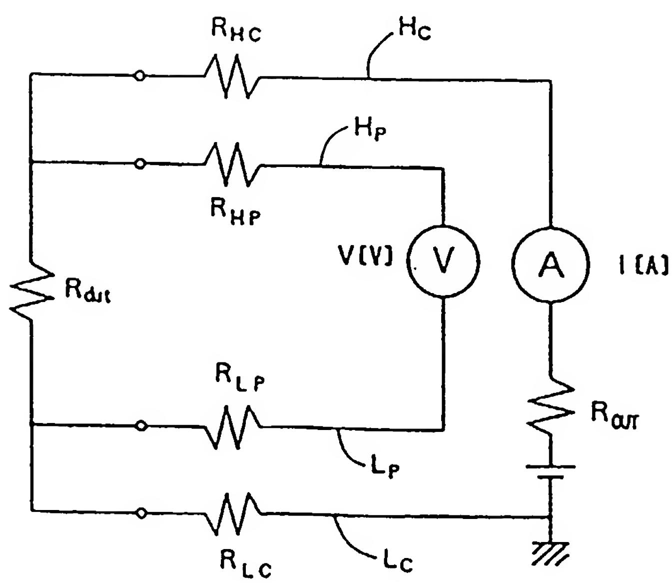
FIG. 1



R_H
V
A
I [A]
R_{dut}
V [V]
R_{OUT}
R_L

FIG. 2



R_{HC}
H_C
H_P
R_{HP}
V [V]
V
A
I [A]
R_{dut}
R_{LP}
R_{OUT}
L_P
R_{LC}
L_C

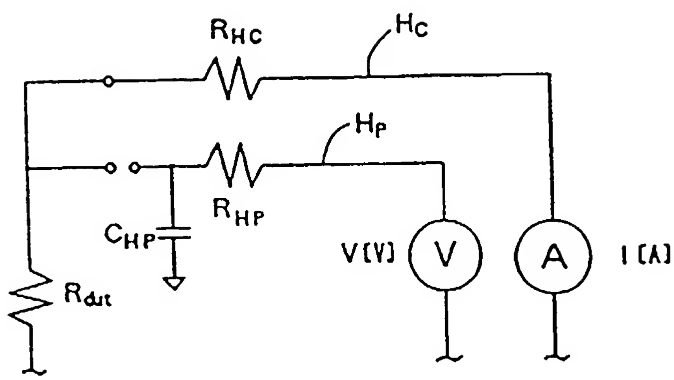

RHC
HC
HP
RHP
CHP
V[V]
V
A
I[A]
Rdut

FIG. 3

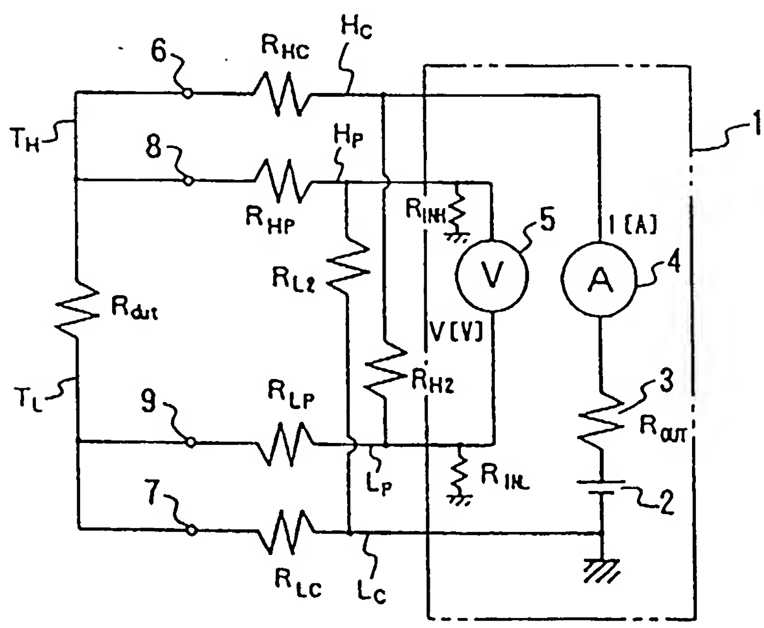
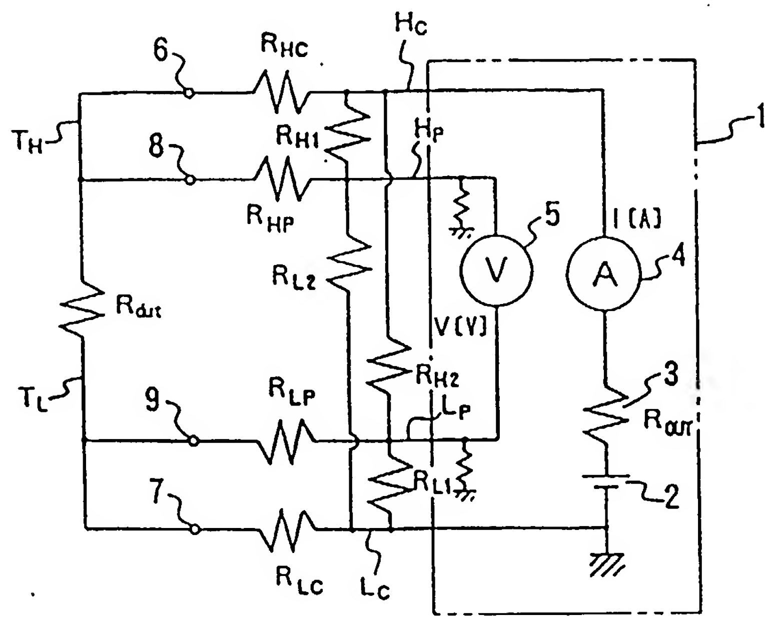
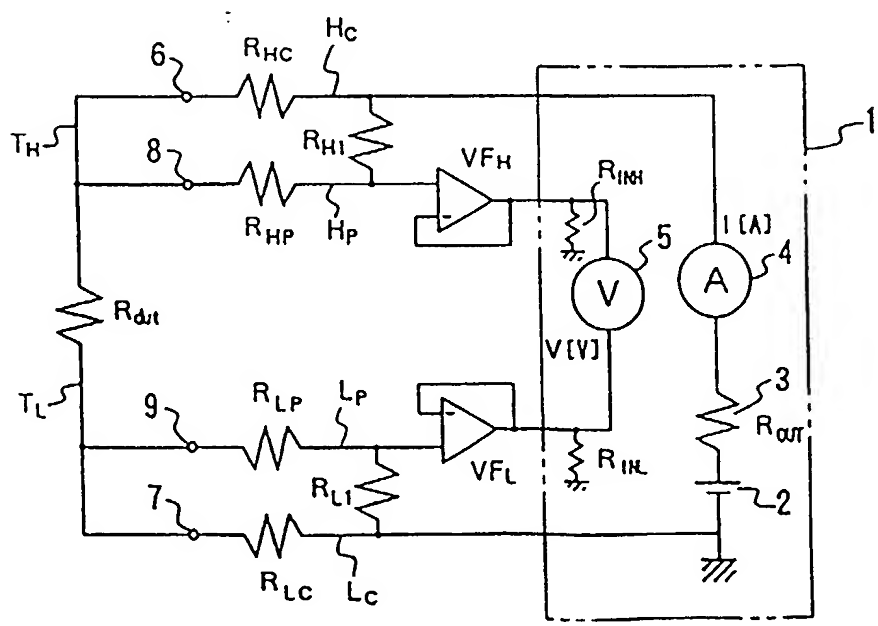

6
RHC
HC
TH
8
HP
RHP
RINH
5
I[A]
RL2
V
A
4
Rdut
V[V]
3
RH2
TL
9
RLP
ROUT
LP
RINL
7
2
RLC
LC
1

FIG. 4



Hc
6
RHC
TH
RH1
Hp
8
RHP
5
I [A]
V
A
4
RL2
Rdut
V [V]
RH2
3
TL
9
RLP
Lp
ROUT
RL1
7
2
RLC
Lc
1

FIG. 5



Hc
6
RHC
TH
RH1
VFH
8
RINH
RHP
Hp
I [A]
5
V
A
4
Rdut
V [V]
3
TL
9
RLP
Lp
ROUT
RIHL
VFL
RL1
7
2
RLC
Lc
1

FIG. 6

IMPEDANCE MEASURING APPARATUS FOR ELECTRONIC COMPONENT

BACKGROUND OF THE INVENTION

The priority document for this application, Japanese Patent Application No. 11-221995, is here incorporated by reference in its entirety.

1. Field of the Invention

The present invention relates to an impedance measuring apparatus for an electronic component using a four-terminal method (Kelvin method).

To simplify the description in this specification, an example has been chosen involving the measurement of a resistance to which DC signals are applied. Due to the natures of DC, the only parasitic parameters generated in a circuit are resistance components. When measurement is applied in the case of AC signals, though the parasitic parameters become impedances which are denoted using complex numbers, the concepts are akin to those for the measurement using DC signals.

2. Description of the Related Art

Hitherto, a two-terminal method, as shown in Fig. 1, is used to measure the impedance of an electronic component. In this case, a measured value of the impedance can be measured as $R_M = V/I$. R_M, which is measured using this method, includes contact resistances R_H and R_L occurring in measurement cables (or terminals), other than the impedance R_{dut} of the electronic component, which is a measurement object. This contact resistance includes lead-wire resistances of the measurement cables or the like. R_M may be expressed as:

$$R_M = V/I = R_{dut} + R_H + R_L$$

When R_H and R_L are very high relative to R_{dut}, making the value of R_{dut} negligible, a measurement error results. The contact resistances R_H and R_L vary whenever contact occurs between the measurement object and the measurement

terminals. Accordingly, the influence of R_H and R_L cannot be removed by means of compensation or the like.

When the measurement error caused by the contact resistances R_H and R_L is not negligible, such as a case in which the measurement object has a low impedance, the measurement may be performed using a four-terminal method, as shown in Fig. 2. In this method, the measured value $R_M = V/I = R_{dut}$ is obtained, and R_H and R_L are avoided as measurement error factors.

However, there are problems in the four-terminal method when contact failure occurs at voltage detection lines (H_P, L_P). For example, when many measurement objects are measured one after another, the H_P line is subject to contact failure, as shown in Fig. 3. If stray capacitance C_{HP} is generated on the H_P line at this time, the stray capacitance appears to have been charged by the voltage obtained on the measurement object before the present measurement of current was obtained. When a measurement object is measured in this state, the following expression is obtained.

$$R_M = V \text{ (previous voltage)}/ I \text{ (present current)} = R_{dut} \quad (1)$$

The value obtained in this manner is not the resistance of the measurement object currently intended to be measured, as it is influenced by the most recent normal measurement of the measurement object. There is a possibility that measurement failure may occur on the L_P line as well as the H_P line, for similar reasons.

Therefore, when a contact failure occurs on a voltage detection line, the measured resistance value is not accurate when a "pure" four-terminal method is used. Because such inaccuracies, there is a risk of delivering defective products instead of good products. In regard to current measurement, when a contact failure occurs at a current-carrying line H_C or L_C, measurement cannot be performed since the current I becomes zero.

It is desirable to use a voltage detection unit having a high input impedances R_{INH} and R_{INL} in the measuring apparatus, yet the input impedances are not infinite. In

addition, since the impedance of stray capacitance of the measurement cable is inserted so as to be in parallel, the input impedance is decreased. Accordingly, the voltage detected at the voltage detection unit is voltage-divided by the contact resistances R_{HP} and R_{LP}, and R_{INH} and R_{INL}. When R_{HP} and R_{LP} become too high to be negligible, a measurement error occurs. Since R_{HP} and R_{LP} vary when contact occurs between the measurement object and the measurement cables, the measurement error due to this cannot be removed by means of a method such as compensation. Furthermore, when measurement using AC signals is performed, there is a possibility that measurement failure may occur because of electrostatic coupling or electromagnetically inductive coupling among the H_C and L_C lines, and the H_P and L_P lines.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an impedance measuring apparatus for an electronic component in which use of a simple circuit prevents a defective product from being inadvertently determined as a good product when contact failure occurs at a measurement terminal thereof.

It is another object of the present invention to provide an impedance measuring apparatus for an electronic component which decreases the measurement error due to contact resistance.

Accordingly, there is provided an impedance measuring apparatus for an electronic component for measuring impedance of the electronic component using a four-terminal method, the impedance measuring apparatus for the electronic component comprising: a first current-carrying line connected to one electrode of said electronic component and a first voltage detection line connected to the other electrode thereof; a first resistor establishing a connection between said first current-carrying line and said first voltage detection line; a second current-carrying line connected to the other electrode of said electronic component and a second voltage detection line connected to the one electrode thereof; and a second resistor

establishing a connection between said second current-carrying line and said second voltage detection line, wherein said first resistor and said second resistor have sufficiently high resistances compared to contact resistances occurring among the electrodes of said electronic component, the current-carrying lines, and the voltage detection lines.

The impedance measuring apparatus according to the present invention may be used to effectively determine whether a product is defective or not when the impedance thereof is lower than a standard value. That is, in a measuring apparatus according to the present invention, when contact failure occurs on any of the measuring terminals, the measured value is decreased by an amount corresponding to the contact resistances. By pulling-down the voltage detection lines, contact failure may be estimated, to reduce or eliminate the risk of delivering defective products as good products.

In the impedance measuring apparatus according to the present invention, it is desirable to have a sufficiently high input impedance of a voltage detection unit of the measuring apparatus. When measurement is performed using AC signals by means of the four-terminal method, there is a case in which a measuring apparatus has a high input impedance using a DC signal, yet has low input impedance for an AC signal due to input capacitance. In addition, even though the input impedance of the measuring apparatus is high, the input impedance thereof is lowered due to stray capacitance of a measurement cable. In these cases, preferably, by inserting a voltage follower having a high input impedance ahead of an input unit of the measuring apparatus, the influence due to contact failure is lessened, which can decrease the measurement error.

Advantageously, the impedance measuring apparatus further comprises: a voltage follower having a high input impedance and inserted on at least the higher-voltage detection side of the voltage detection lines provided among said first resistor, said second resistor, and the measuring apparatus.

In addition, the impedance measurement can be performed by inserting resistors in the measuring circuit. Since no particular contact detection circuit is

required, the measuring apparatus in accordance with the present invention may advantageously be realized with low cost.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a circuit diagram of an impedance measuring apparatus using a conventional two-terminal method;

Fig. 2 is a circuit diagram of an impedance measuring apparatus using a conventional four-terminal method;

Fig. 3 is a circuit diagram in a case in which contact failure occurs on a voltage detection line using the conventional four-terminal method;

Fig. 4 is a circuit diagram of a first embodiment of impedance measuring apparatus according to the present invention;

Fig. 5 is a circuit diagram of a second embodiment of the impedance measuring apparatus according to the present invention; and

Fig. 6 is a circuit diagram of a third embodiment of the impedance measuring apparatus according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Fig. 4 shows a first embodiment of the impedance measuring apparatus according to the present invention. This measuring apparatus is used for estimation in a case in which a product is defective when the impedance thereof is lower than a standard value.

A first resistor R_{H2} is connected among the current-carrying line H_C connected to one electrode T_H of the measurement object R_{dut}, the voltage detection line L_P connected to the other electrode T_L. A second resistor R_{L2} is connected between the current-carrying line L_C connected to the other electrode T_L and the voltage detection line H_p connected to the electrode T_H. The resistances (for example, 50 k Ω) of these first and second resistors R_{H2} and R_{L2} are preferably set so as to be substantially higher than values (normally, equal to or below 10 Ω) which are normal for the

contact resistances R_{HC}, R_{LC}, R_{HP}, and R_{LP}. That is, it is preferred that the resistances are related as follows.

$$R_{H2} >> R_{HC}, R_{HP}$$
$$R_{L2} >> R_{LC}, R_{LP}$$

In the measuring apparatus in Fig. 4, when contact failure occurs on the voltage detection lines H_P and/or L_P, the measured value R_M is typically related as follows.

$R_M = - R_{LC}$ (when the H_P line is not in contact)

$R_M = - R_{HC}$ (when the L_P line is not in contact)

$R_M = - R_{dut} - R_{LC} - R_{HC}$ (when neither H_P nor L_P is in contact)

Accordingly, when contact failure occurs on the voltage detection lines H_P and L_P in this manner, by pulling-down the voltage detection lines, the measured value decreases. Hence, in a manner of selection in which a product is judged to be defective when the resistance of the product is less than a standard value, the risk of inadvertently selecting a defective product as being a good product may be reduced or avoided.

Fig. 5 shows a second embodiment of the impedance measuring apparatus according to the present invention, wherein the second embodiment is a variation of the embodiment in Fig. 4. In Fig. 4, when contact failure occurs, a measured value may be negative in some cases. In those instances that it is desired for the measured value to be positive, or in the case in which the measured value is desired to be in the proximity of a predetermined resistance even though contact failure occurs, as shown in Fig. 5, the resistors R_{H1} and R_{L1} are each preferably connected between the corresponding current-carrying lines and the corresponding voltage detection lines that are in contact with the same electrodes in addition to the resistors R_{H2} and R_{L2}. The resistances (for example, 100 k Ω) of these resistors R_{H1} and R_{L1} are preferably set so as to be substantially higher than values (normally, equal to or below 10 Ω)

which are normal for the contact resistances R_{HC}, R_{LC}, R_{HP}, and R_{LP}.

In the above-described measuring apparatus, when contact failure occurs on the voltage detection lines H_P and/or L_P, the measured value can be seemingly offset to some extent by causing the voltmeter 5 to detect what is obtained by voltage-dividing the applied voltage using these resistors R_{H1}, R_{L1}, R_{H2}, and R_{L2}. These resistances and the voltage-divided ratio are selected in accordance with the measurement object R_{dut}.

Fig. 6 shows a third embodiment of the impedance measuring apparatus according to the present invention.

In order to actually use a method in which the voltage detection lines are pulled-down, it is preferred that the input impedances R_{INH} and R_{INL} of the voltage detection unit of the measuring apparatus 1 be sufficiently high. For example, there is a case in which a measuring apparatus has a high input impedance for a DC signal, yet has a low input impedance for an AC signal due to input capacitance. In addition, there is a case in which the input impedance of the measuring apparatus is lowered due to stray capacitance of a measurement cable. In these cases, when contact resistances are added to be in series with the corresponding voltage detection lines H_P and L_P, the measurement error increases.

Accordingly, in this embodiment, voltage followers VF_H and VF_L having high input impedances are inserted ahead of the voltage detection unit (H_P, L_P) of the measuring apparatus 1, whereby the measurement error due to contact resistances decreases. The voltage followers VF_H and VF_L serve to greatly enhance the input impedance of the measurement system observed from the measurement object side as well as to greatly reduce output impedance of the measurement object observed from the measuring-apparatus side (impedance conversion). In order to avoid the occurrence of unnecessary noise, a low-noise type operational amplifier or the like is desired to be used to form the voltage followers VF_H and VH_L.

In addition, it is effective that the voltage followers VF_H and VF_L are provided on the higher-voltage detection side of the voltage detection lines H_P and L_P.

It should be understood that the present disclosure of preferred forms of the present invention arc exemplary and not limited in every respect. The scope of the invention is defined by the appended claims rather than by the description preceding them, and all changes that fall within the scope of the claims, or equivalence of such scope of the claims. are intended to be included by the claims.

Attention is directed to Application No. 0018664.3 (Serial No. GB2353366A) from which this application is divided.

CLAIMS:

1. An impedance measuring apparatus for an electronic component for measuring impedance of the electronic component using a four-terminal method, the impedance measuring apparatus for the electronic component comprising:

a first current-carrying line connected to one electrode of said electronic component and a first voltage detection line connected to the other electrode thereof;

a first resistor establishing a connection between said first current-carrying line and said first voltage detection line;

a second current-carrying line connected to the other electrode of said electronic component and a second voltage detection line connected to the first-mentioned electrode thereof; and

a second resistor establishing a connection between said second current-carrying line and said second voltage detection line,

wherein said first resistor and said second resistor have substantially higher respective resistances compared to contact resistances occurring among the electrodes of said electronic component, the current-carrying lines, and the voltage detection lines when contact is made.

2. An impedance measuring apparatus for an electronic component according to Claim 1, further comprising:

a voltage follower having a high input impedance and inserted on at least the higher-voltage detection side of the voltage detection lines provided among said first resistor, said second resistor, and the measuring apparatus.

3. An impedance measuring apparatus substantially as hereinbefore described with reference to Figures 4 to 6 of the accompanying drawings.

Amendments to the claims have been filed as follows

CLAIMS:

1. An impedance measuring apparatus for an electronic component for measuring impedance of the electronic component using a four-terminal method, the impedance measuring apparatus for the electronic component comprising:

a first current-carrying line connected to one electrode of said electronic component and a first voltage detection line connected to the other electrode thereof;

a first resistor establishing a connection between said first current-carrying line and said first voltage detection line;

a second current-carrying line connected to the other electrode of said electronic component and a second voltage detection line connected to the first-mentioned electrode thereof; and

a second resistor establishing a connection between said second current-carrying line and said second voltage detection line,

wherein said first resistor and said second resistor have substantially higher respective resistances compared to contact resistances occurring among the electrodes of said electronic component, the current-carrying lines, and the voltage detection lines when contact is made.

2. An impedance measuring apparatus for an electronic component according to Claim 1, further comprising:

a voltage follower having a high input impedance and inserted on at least the higher-voltage detection side of the voltage detection lines provided among said first resistor, said second resistor, and the measuring apparatus.

3. An impedance measuring apparatus substantially as hereinbefore described with reference to Figures 4 and 5 of the accompanying drawings.